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for

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Planetary Quarantine Department

Sandia Laboratory, Albuquerque, New Mexico

October 1966

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I - SYSTEMS SUPPORT ACTIVITIES

(A) Ultrasonic Particle Disseminator Development

In an effort to provide parameters associated with initial microbial loading on spacecraft surfaces for the Planetary Quarantine Mathematical Model, a study has been initiated to determine the model best suited for collection and retention of viable particles that may be present in the atmosphere of a defined environment. One of the first steps in this study has been the development of a Sonic Disseminator which is used to load a static clean-room atmosphere with stable, predictable concentrations of dry bacterial spores. This device was designed so that a means of loading a test atmosphere with very low concentrations of spores which are used as a surface loading mechanism would be available. To obtain repeatable aerosol loadings of single microorganisms is a very difficult task with existing commercial equipment. However, the use of sonic energy in this dissemination technique not only tends to separate clumps of spores but also provides the mechanism for release of very small, yet predictable, numbers of spores into a defined atmosphere.

(B) Vacuum Probe Development

The other major development has been on a Vacuum Probe which is used to retrieve bacteria from surfaces for assay purposes. The first modification of the Vacuum Probe has consistantly yielded removal efficiencies of 90-100% when loading a smooth aluminum surface with dry *Bacillus subtilus* var. *niger*, 77-94% when loading with wet *Bacillus subtilus* var. *niger*, and 94-99% when loading with bacteria contained in garden soil and human skin flakes. Work is now underway to optimize and define not only the probe but also the associated tubing and sampler which are all interconnected within the complete assay system.

(C) Fine Particle Physics Studies

Along with the final development work on the Vacuum Probe a study of viable particle adhesion characteristics and a study of the physics of viable particle retention on surfaces have been initiated. The combination of these studies will provide the physical model upon which the parameters of the mathematical model can be based.

(D) High Rate Aerosol Particle Monitor

A production unit is scheduled for delivery to Sandia Corporation in late November, 1966. This unit will sample air at the rate of 1 CFM with the possibility of 2 CFM.

A report, SC-RR-66-585 entitled, "Development of Increased Sampling Rate Monitoring System", is scheduled for publication November 2, 1966, covering the development of the high rate sampler system.

(E) Microbiological Support Studies

In an effort to more exactly define some of the biological models which are being transferred into mathematical models, several microbiological support studies are being initiated. One of these is concerned with determining the relationship between bacterial die-away and the relative humidity of the atmosphere in which the bacteria reside. At this point, 33%, 50% and normally variable ambient laboratory relative humidities are being utilized in the testing procedure.

Another effort concerns determining the microbiological profile of a clean, laminar-flow hospital operating room during its use. Aerosol samplers have been placed at strategic points not only around the operating room equipment but also very close to the incision of the patient. Hopefully, the data from the samplers placed near the floor will provide an indication of the actual bacterial loading caused by shedding of workers during their movement, and data from the point of incision will correlate with the possible contamination at points near a convenient work elevation in a tightly controlled environment. The tightly controlled environment of the operating room can then be compared with proposed spacecraft assembly operations to obtain some indications of contamination ranges.

II - SYSTEMS STUDIES ACTIVITIES

(A) Model of Program Objectives

A model has been developed which relates total planetary exploration objectives to spacecraft oriented subobjectives. Each of the phases (lander, flyby and orbiter) is represented in the model by an expression of the form

$$P^K = \sum_{J=0}^{M} (1-P_C)^{N+J} \binom{N+J-1}{J} P_S^N (1-P_S)^J$$

where

P - is the probability of total exploration program success,

K - is a number, $0 \leq K \leq 1$, "proportioning" the success to the phase in question,

P_C - is the probability that a given mission biologically contaminates the planet (assumed constant),

P_S - is the probability that a given mission be successful

N - is the minimum number of successful missions needed to successfully complete the given phase of the total exploration program, and

M - is the number of additional missions that one is willing or able to launch in order to increase the probability of success of this program phase.

The above expression represents the probability of completing N missions successfully in N + M total missions (in the phase question) without biologically contaminating the planet. Accordingly, P^K is called the "probability of successfully completing" the phase in question. The model assumes that the objective of any given phase may be stated as "the probability of successfully completing the phase should not be less than some prescribed lower bound," or notationally, $P^K \geq \hat{P}^K$.

With this objective, for each fixed set of parameters K, N, M, P_S, one may obtain a requirement on P_C of the form $P_C \leq \hat{P}_C$. That is, the probability of biological contamination from any spacecraft may not exceed some upper bound if P^K is to be greater than or equal to $\hat{P}^K$.

Because of the natural uncertainty surrounding many of the parameters P,K,N,M,P_S, the model has been analyzed using many combinations of values for these parameters.

The probability, P_C, of biological contamination from a single spacecraft, is related, in the model, to P(0), the probability of having no viable terrestial microorganisms aboard the spacecraft. Thus, the requirement $P_C \leq \hat{P}_C$ leads to a requirement on P(0) of the form $P(0) \geq \hat{P}(0)$, that is, the probability that the spacecraft is sterile must not be less than some lower bound $\hat{P}(0)$. This latter requirement is spacecraft oriented, and becomes a subobjective that must be achieved. The number P(0) is calculated for many combinations of values of K,N,M, and P_S.

This model is intended as a first step in developing a model which incorporates both experimental objectives and non-contamination objectives. There is a tradeoff between these two, and a model is needed which allows this relationship to be analyzed. It is hoped that the presentation of this model will stimulate further interest in this area, and lead to the development of a model which is acceptable to the planetary quarantine community.

(B) Sterilization Models

The sterilization model currently used for predicting the probability, P'(0), that a spacecraft is sterile immediately after the terminal sterilization heat cycle assumes that the probability that a single microorganism is alive at time t in a given thermal environment is of the form (exponential death model)

$$p(t) = 10^{-\alpha t}$$

where α is a constant dependent upon the thermal environment and type of microorganism involved. If one enters the sterilization cycle with a population of n_0 microorganisms of a fixed type and assumes that the deaths of these microorganisms are independent of one another, then the probability, $P(k)$, of having $k(k \leq n_0)$ microorganisms remaining at time t is

$$P(k) = \binom{n_0}{k} [p(t)]^k [1-p(t)]^{n_0-k},$$

where $\binom{n_0}{k}$ is the binomial coefficient representing the number of ways k things may be chosen from among n_0 things. Using this model, the expected number of microorganisms at time t, denoted $E(t)$, has the form

$$E(t) = n_0\ 10^{-\alpha t}.$$

Normally, one compares experimental data with $E(t)$ in attempting to decide whether such an exponential model is appropriate.

Much of the research data related to planetary quarantine varies considerably about $E(t)$. This is particularly true when the numbers measured are small. Furthermore, very recent studies indicate that the past environmental history of a microorganism (as well as sterilization thermal environment) plays an important role in a microorganisms' survival.

Thus an investigation has been initiated to examine other possible models which are not in contradiction with existing data and which contain some hereditary factor.

(C) Literature Survey

A survey of literature pertinent to the planetary quarantine problem is being undertaken. Literature sources are:

1. general aerospace literature abstracts,
2. NASA literature abstracts,
3. Planetary Quarantine Organization, NASA, research publications
4. literature obtained at or through attendance at pertinent meetings, and,
5. retrospective search service provided by the Technology Application Center, UNM, under the auspices of the Office of Technical Utilization, NASA.

It is expected that this compendium will be useful in:

(i) determining the state-of-the-art in areas related to planetary quarantine,

(ii) finding areas in which more research and development may be advisable,

(iii) obtaining more comprehensive data upon which to base quantitative models, and

(iv) obtaining data for use in evaluating the values of model parameters.

Articles are now being collected and categorized, and a document surveying these, in relation to the current program development, has been started.

III - PUBLICATIONS AND PATENTS

(A) Publications

1. Sherry, E. J., and Trauth, C. A., "An Assembly Contamination Model," SC-RR-66-421, July, 1966.
2. Beakley, J. W., Whitfield, W. J., and Mashburn, J. C., "Deposition of Nutrients to Surfaces by Rodac Plates," SC-RR-66-386, September, 1966.
3. Beakley, J. W., Whitfield, W. J., and Mashburn, J. C., "Evaluation of the Efficiency of a Class 100 Laminar-Flow Clean Room for Viable Contamination Cleanup," SC-RR-66-385, September, 1966.

(B) Patents

U. S. Patent No. 3,273,323, covering a Laminar Flow Air Hood Apparatus, issued on September 20, 1966, to W. J. Whitfield, 2572.

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